MAIN CAUSES OF MARINE ECOSYSTEMS TRANSFORMATION

Population and ecosystem evolution of marine biota is determined by natural environmental development. Climatic changes are without any doubt the crucial factor. Still, the human activities in the 20th century were not the least cause of undesirable changes in marine ecosystems of commercial importance. Seismic surveys, pilot shelf boring, exploitation of many thousands of vessels, growing discharge of sewage and industrial wastes, radioactive background and many other are to be added to the list (G.G. Matishov et al. 1997, *Chemical processes in the ecosystems of the northern seas*).

RUN-OFF REGULATION AND LOSS OF SPAWNING AREAS

Large scale construction of dykes on the Volga, Don, Dnieper rivers caused dramatic changes in bioproductivity of the seas in the southern part of Russia (**Fig.** 44). Run-off regulation led to loss of spawning areas of sturgeon family and other valuable marketable species and to drastic decrease of river outflow to the Azov, Caspian and Black seas. Biochemical and hydrochemical balance of the reservoirs was upset, too. It turned out a catastrophe for reservoirs with low salinity. River outflow to the Azov Sea decreased by over 30 % (24 m^3 per year) after building of only one dyke in Tsymlansk. The dam cut off the sea all spawning areas of white sturgeon and up to 50 % spawning areas of sturgeon, sevryga and herring. Long term shortage of fresh water was compensated by salt water of the Black Sea. Observations carried out for decades show, that the Azov Sea receives 30–40 km^3 of waters of the Black Sea. Total outflow deficiency was compensated by increase in salinity of the Azov Sea by average 3‰ (Bronfman et al. 1979).

Spring freshet reduction to 35% of annual mass flow brought about a general decrease in abundance, supply and redistribution of biogenes which were captured between the dam. The Azov Sea is going through the predicted period of salinization. Abnormal salinity brought down the freezing point of sea water and formation of ice here is now delayed. As the result, shallow waters cool down right to the bottom to such extent, that fish body fluids freeze and blood curdles. High winter water level in reservoirs with regulated run-off causes intensive «blooming» of phytoplankton in February-March (Sapoznikov 1995, Kovaleva, 1998). This brought about considerable redistribution of positions of certain groups of phyto- and zooplankton and benthos. E.g. Blue-green microalgae nearly lost their position altogether in marine ecosystem in the 1970s. Pyrophyte algae abundance dropped dramatically and influence of diatomaceous algae grew stronger. Such undesirable aliens as *Ctenophora* moved in.

Phytoplankton biomass grew up by dozens of times during the past 20 years in the North–West of the Black Sea (Zaitsev 1992, Fashchuk 1998). «Red tide» is consequence of excessive accumulation in the bottom layer of organic matter formed after «blooming» algae die off. At the present time its quantity increased by four times and may vary during summer time from 15 to 50 mg/l (Torgunova 1994). This index for the Black Sea waters in general has grown over last 30 years by 6–8 kg/m^2 (Torgunova 1994). Consequently it increased oxidation rate of excessive organic matter in bottom layer by 3–4 times as compared to natural oxidation rate (Faschuk and Sapozhnikov 1999).

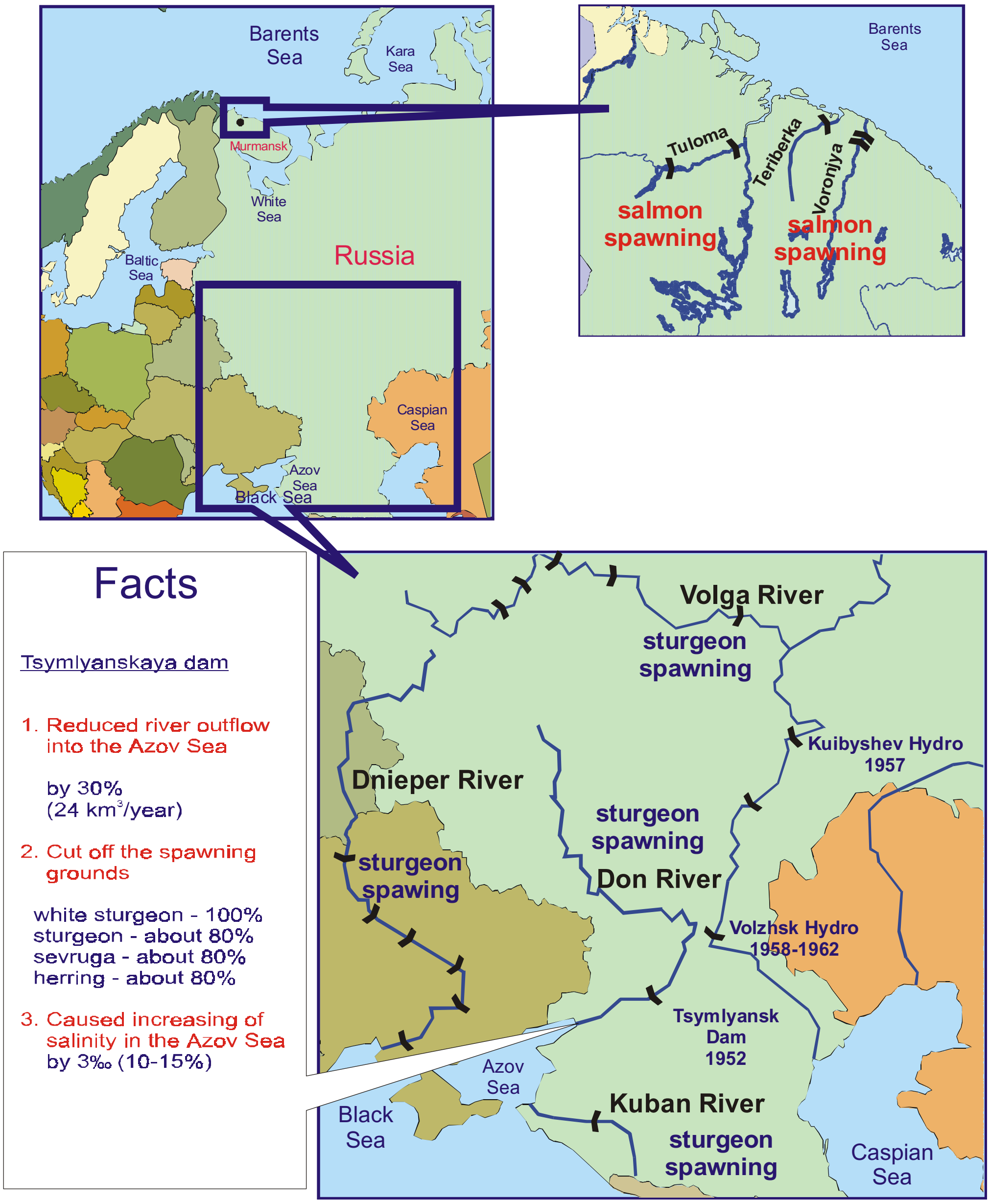

Fig. 44. Run-off regulation and loss of spawning grounds (rivers with cascades of dams)

The presence of medusa in the Azov Sea implies that water salinity is high. Every time its concentration reaches maximum admissible threshold, danger of mass death through low water oxygen in winter appears. In 1974, the total weight of medusa migrated from the Black Sea comprised 2 mln t, in 1976 its biomass was over 16 mln t.

Thus run-off regulation, discharge of sewage and industrial wastes and fertilizers cause increase of microalgae biomass by dozens of times, «blooming» and phenomenon of mass death. Hydrogen sulfide contamination of benthic waters expanded over vast areas in the North-West of the Azov and the Black seas (**Fig.** 45).Oxygen deficiency annually causes death in bottom communities and fish, its total biomass amounts up to several millions tons.

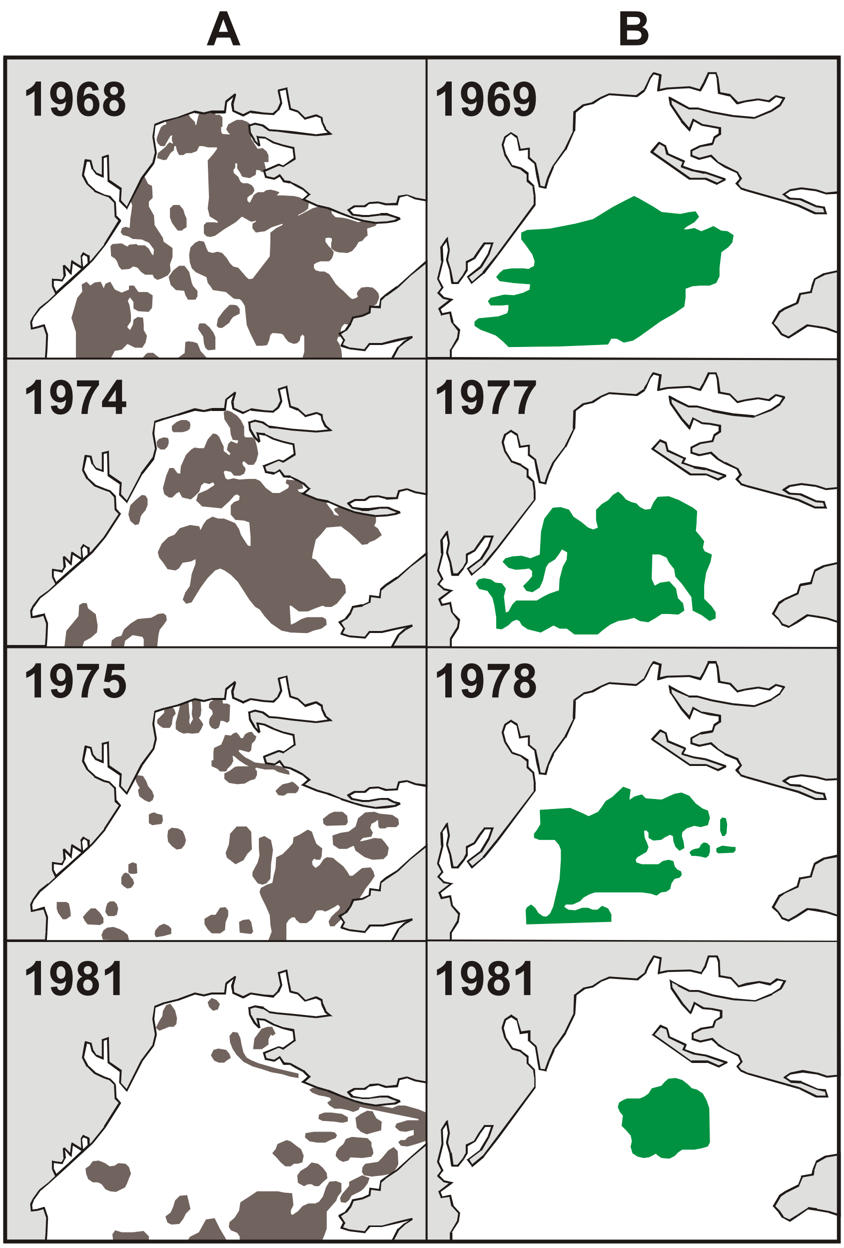

Fig. 45. Shrinking of the phyllophora (B) and blue mussels (A) areas in connection with the hydrogen sulphide contamination on the north-west part of the Black Sea shelf (the 1960-80s) (by Faschuk, 1995)

In the Barents and White seas basins the same situation can be found at major rivers (Teriberka, Tuloma, Voronja) of Kola peninsula where 17 dams prevent salmon from passing natural spawning grounds.

Water intake equipment of all kinds contributes to destruction of sea reservoirs bioproductivity. E.g. There are approximately 1100 water intakes only in the Azov-Don basin extracting annually 7 km^3 of river outflow, 4 km^3 of them are not returned (Kovtun and Syrovatka 1997). Despite introduction of fish protecting devices to 80% of water intakes their efficiency is still low and therefore annual fish death rate still amounts to thousands of tons.

MARINE NAVIGATION AND RIVER-SEA TRANSPORTATION

As has been stated before, thousands of vessels traveling from continent to continent bring with them exotic fauna. Sea organisms are occasionally brought in attached to the bottoms of vessels or with ballast waters. Many aliens are characterized by high ecological flexibility and high rate of natural reproduction, and they develop abundant communities and consequently change species structure and food pattern of ecosystem.

Sea river shipping is one of the most negative factors. Its role radically changed with the collapse of the USSR and the consequent increase in importance of ports in the South of Russia (Astrakhan, Azov, Taganrog, etc.). Vessels with 3–5m draught disturb environmental balance of organisms inhabiting shallow waters (5–10 m). Other shipping related phenomena are dredging, acoustic pollution, cavitation, stirring up of silt bottom, deforestation of coastline and oil spillage. Through the canals dug in shallow water of the Azov Sea alone 7,000 vessels pass annually and this number is still growing.

CHEMICAL CONTAMINATION OF MARINE ENVIRONMENT

Influence of chemical contamination on marine biota life cycle is well known (**Fig.** 46). Contemporary totality of data provides us with firm grounds to postulate, that offshore ecosystems of the Barents and the White seas are characterized by a very low degree of chemical contaminants accumulation in biota (Matishov 1992, Matishov et al. 1994; G.G. Matishov et al. 1997, *Chemical processes in the ecosystems of the northern seas*). E.g. Concentration of artificial radionuclides in marine organisms is lower than natural background (**Fig.** 47). Semi-isolated contained sea basins situated in the areas with high levels of industrial development are most contaminated. These are the Azov, the Baltic sea, the north-west of the Black Sea, and the northern part of the Caspian Sea. Contaminants concentration in environment and biota on many of these shelves exceeds maximum allowable concentration (MAC). E. g. The most dangerous for the Black and Azov seas industries processing oil hydrocarbons are situated in Sevastopol, Novorossiysk, Batumi (**Fig.** 48). The Dnieper, Dniester and Danube rivers bring 60% of the total industrial and domestic sewage annually (about 1 km^3). Anomalous concentrations of phenol in water (maximum allowable concentration exceeded by 52 times) led to closing down of beaches in 1987 in Odessa (Fashchuk 1998). The Black Sea received several tons of pesticides annually which arrived through the Straight of Kerch as their concentration in the Azov Sea exceeded that in the Black Sea by the order of magnitude (434 nanograms/ liter).

Heavy metals represent the dangerous toxicants most often registered in sea water. Concentration of iron in sea water in the Caspian Sea increased considerably over last 15 years: c.f. concentration of iron in the 1980s was 50 mcg/l, concentration of 200 mcg/l was registered at the western coast recently which is 4–5 MACs (Kostrov and Panarin 1997). Concentration of metals in fish organisms (average) ranges from 0.2 to 200 mg/kg: concentration of iron ranges from 24.7 (goby) to 126 (Caspian roach, goby); zinc – from 11.8 (goby) to 53.0 (Caspian roach, zarthe). Concentration of pollutants including heavy metals in bottom sediments of sea reservoirs is an extra danger. Most of the valuable marketable fishes, crustaceans and mollusks live at bottom or close to bottom.

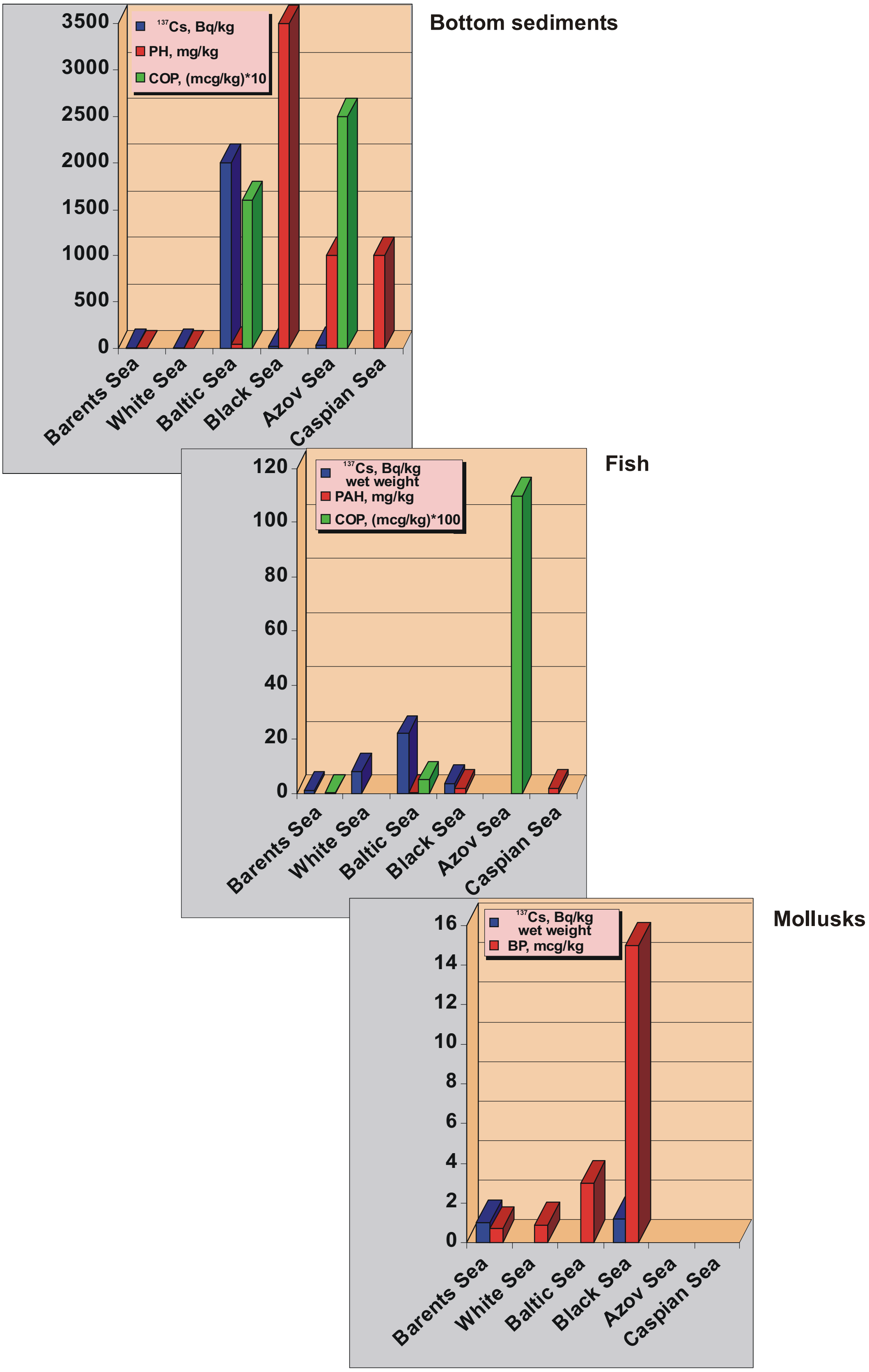

Fig. 46. Artificial radio-nuclides (^{137}Cs), oil hydrocarbons and chlororganic pesticides in bottom sediments, commercial fishes, and mollusks in the seas of Russia (comparative analysis)

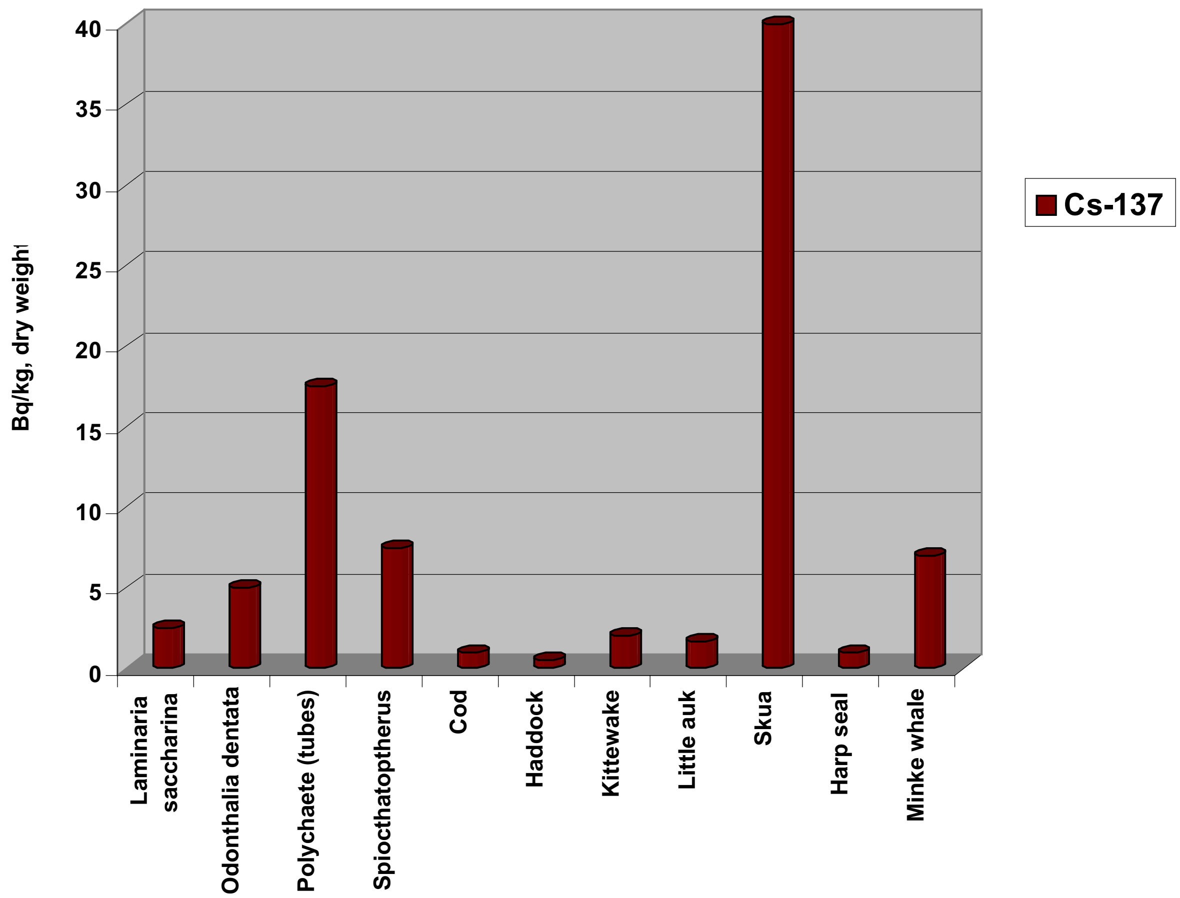

Fig. 47. Concentration of ^{137}Cs in different organisms inhabiting the Barents Sea (Matishov G. G. and Marishov D .G. et al. 1997)

Consequently contamination is transferred through food chain to birds, seals (that is to the top of the ecological pyramid) and to humans. E.g. Concentration of ^{137}Cs in the bottom sediments of Bay of Taganrog is 100 Bq/kg and in the Barents Sea shelf only 1 to 20 Bq/kg (**Fig.** 49, 50) (Matishov et al. 1998).

Long term contamination of the Black and Azov seas basins is one of the reason for changes in spawning behavior, density and schedule of adult fish migration towards coastline, year-classes characteristics and quality of gonad products. The leading role in development of these negative factors belongs to such accumulating toxicants as lead (in liver), and mercury and some DDT metabolites (in gonads) (Dudkin et al. 1997). General disorders of reproductive function detected in many fishes, including sturgeon family, are hermaphroditism, disintegration and resorbtion of gametes, oocyte amitosis at the stage of cytoplasm growth. All these in the course of time will result in degradation of genetic resources of populations.

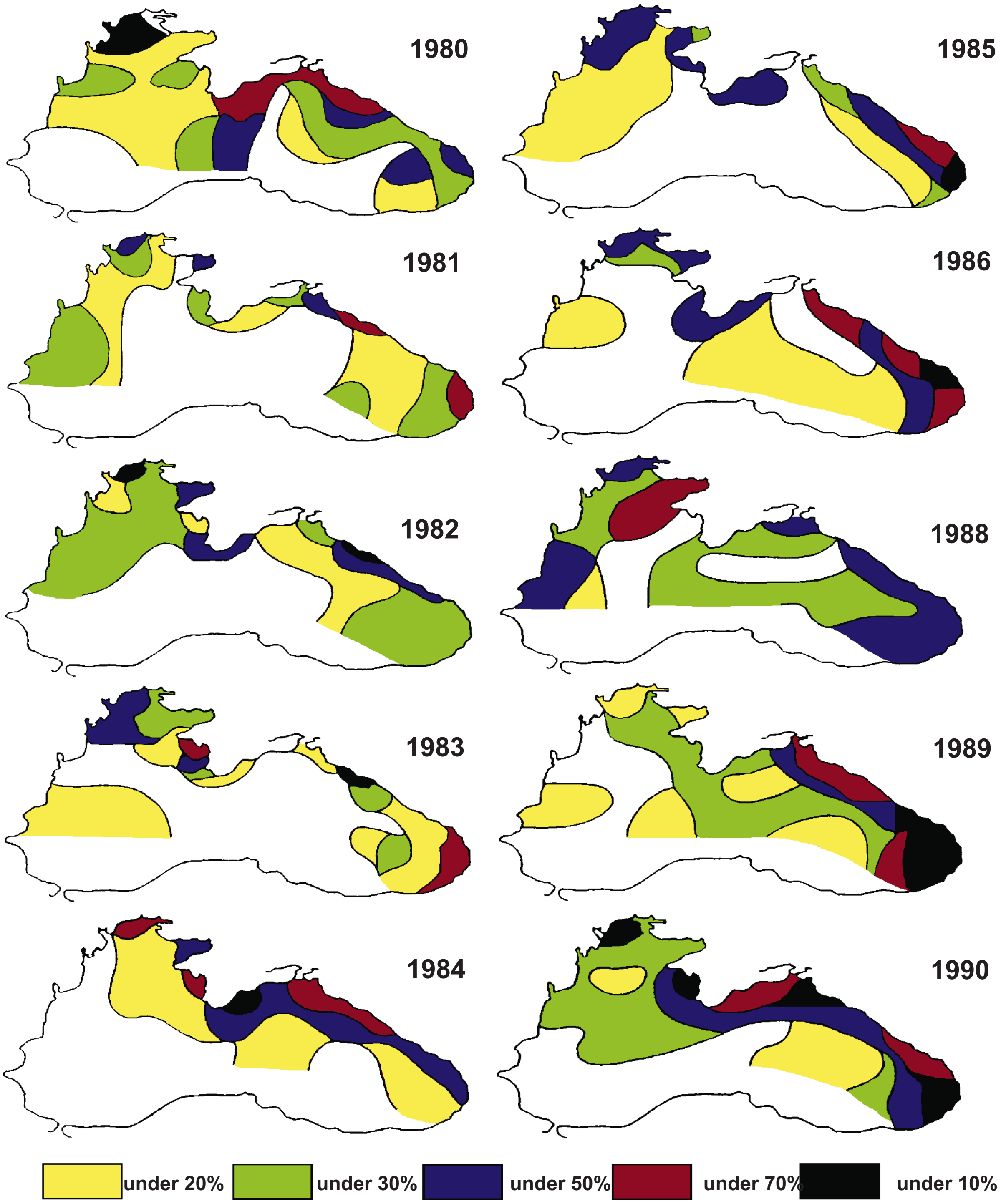

Fig. 48. Frequency of oil products films (%) on the Black Sea surface by the aerial observations data (Fashchuk 1998)

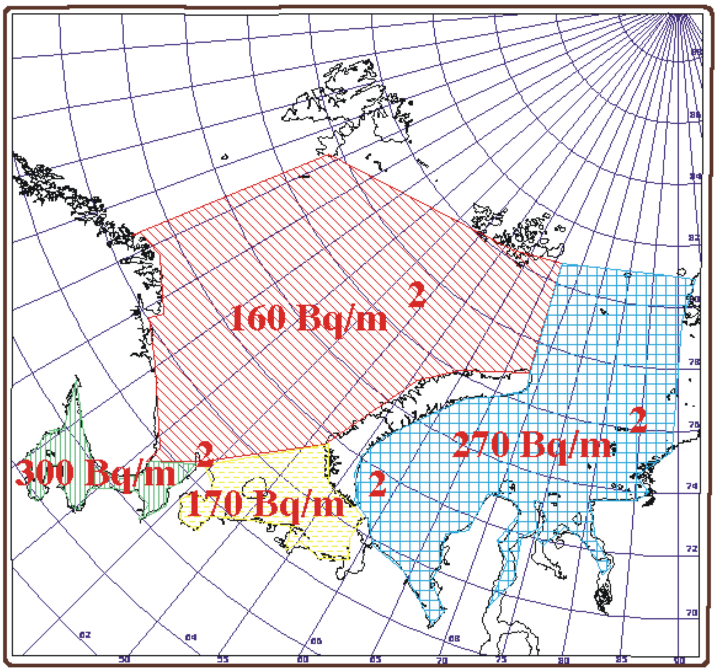

Fig. 49. Maximum concentrations of ^{137}Cs (Bq/m^2) in the bottom sediments of the Barents, the Kara and the White seas

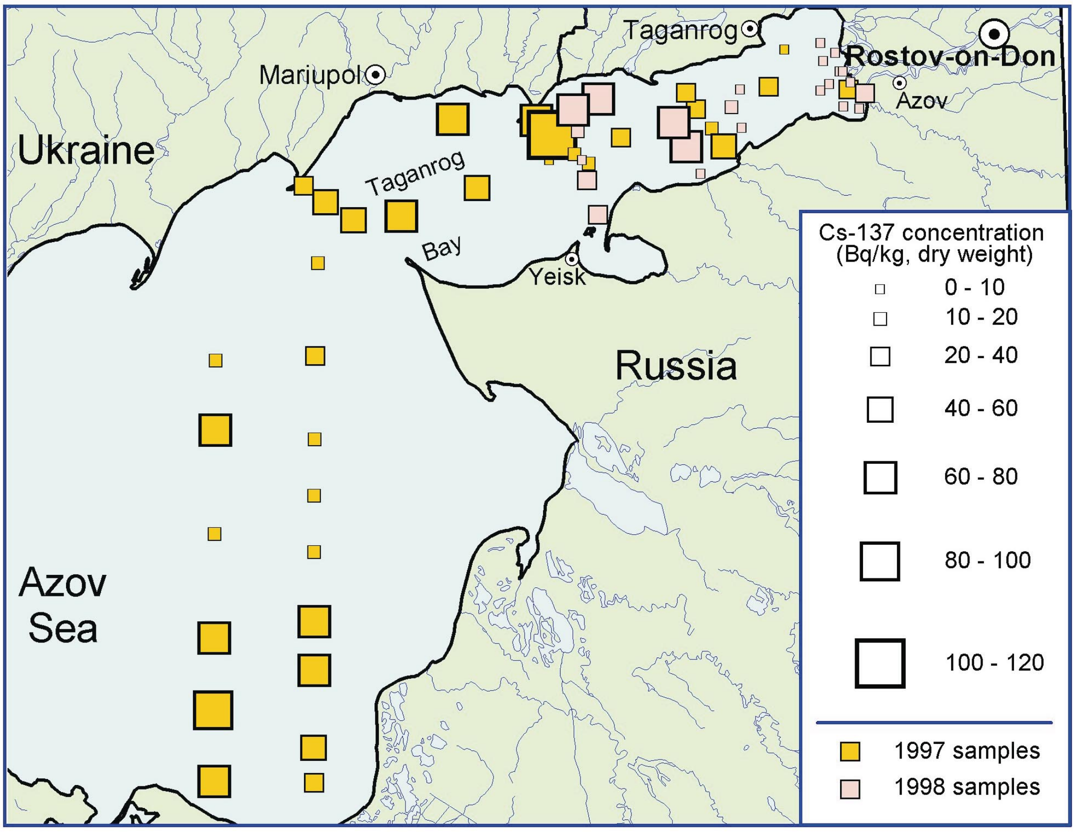

Fig. 50. Contents of ^{137}Cs in the surface layer of bottom sediments in the Azov Sea (based on MMBI investigations in 1997-98)

FISHERY MORTALITY IS THE MAJOR THREAT

Excessive stress of whale hunting and fisheries of countries that exercise whaling, sealing, fishing and exploitation of other bioresources (mollusks, algae, etc.) is to be regarded as the major source of stress among other anthropogenic factors affecting ecosystems in the 20th century. The over exploitation by fisheries and hunters is internationally recognized by scientists and practical workers (**Fig.** 51). Obviously death by fishery triggered irreversible disruption of inter-relations within marine ecosystems and particularly in the marketable stock structure.

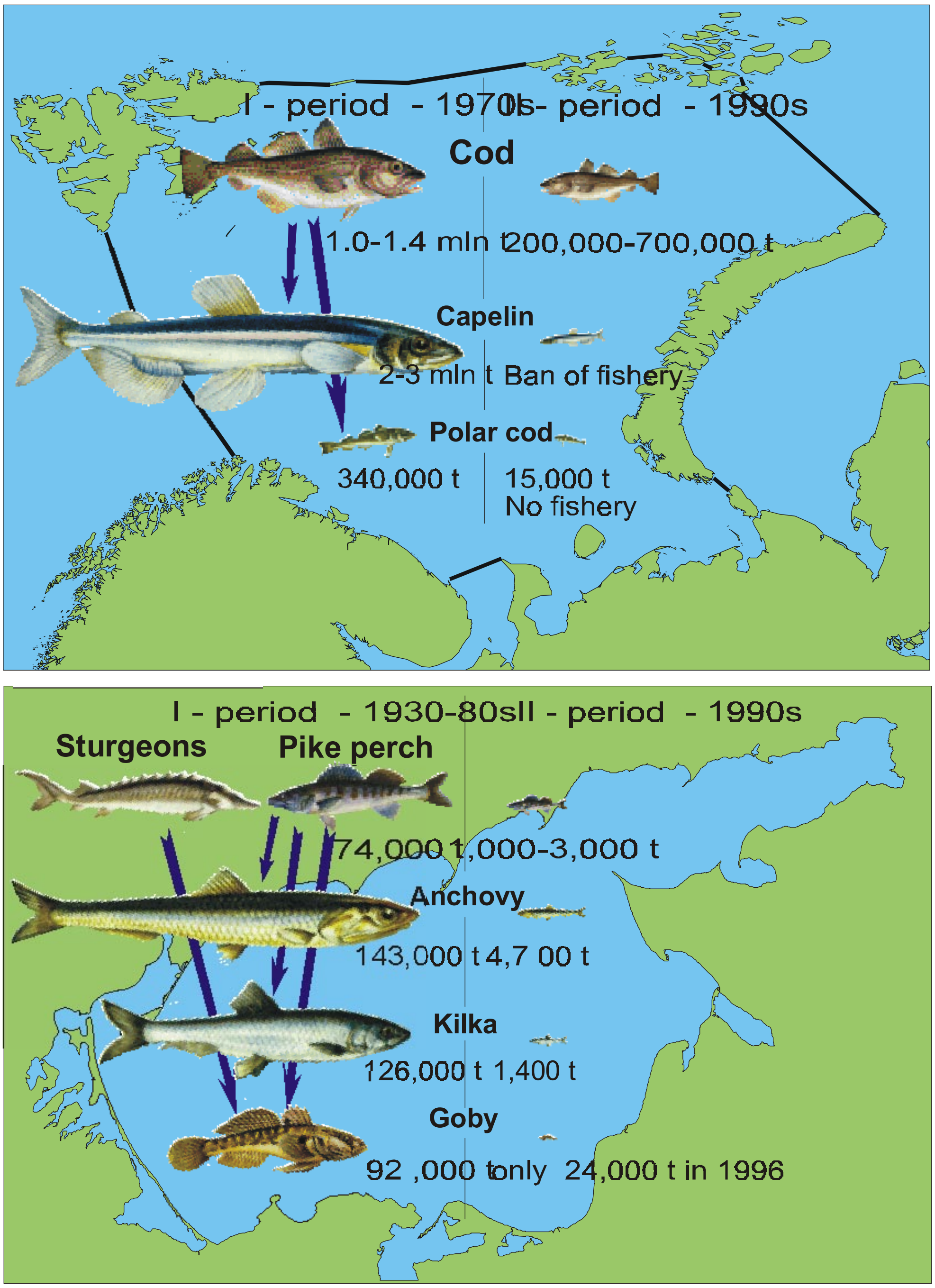

Fig. 51. Ratio of the main fish species catch and their forage objects in the Barents and Azov Sea

Fish is the key element of ecosystems and a bioresource of primary importance. Natural stock number fluctuations are characteristic of all fish species. Marketable fishes serve as an indicator of marine ecosystem dynamics and death by fishing analysis clearly shows it. Yields of fisheries back in the past in the Barents Sea could comprise up to 4 mln t and in each of the Southern seas yields were 400,000–600,000 t. It is but natural that yield of such traditional marketable species as salmon, sturgeon, cod, zander and others decreased 10 fold and more (**Fig.** 52).

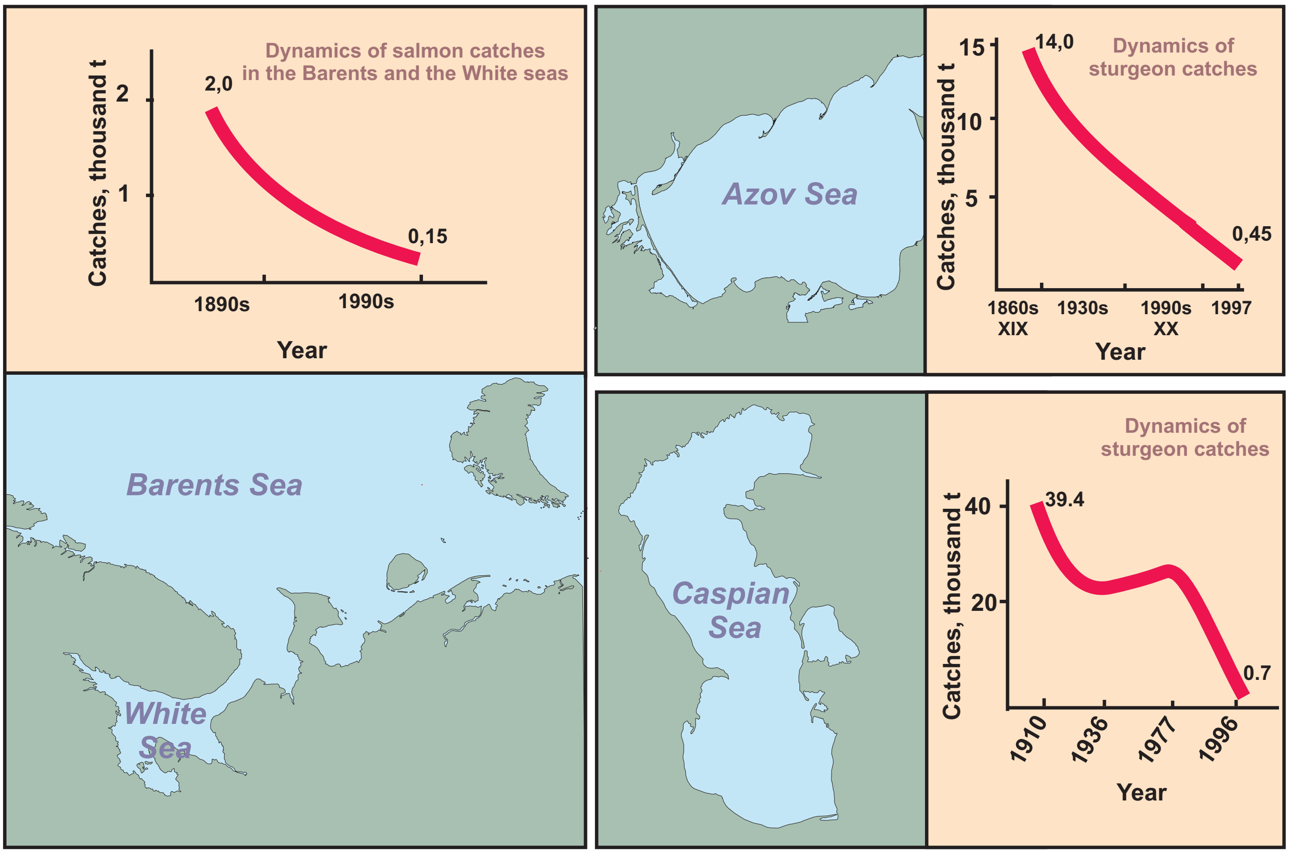

Fig. 52. Dynamics of valuable fish species catches in the seas of the European part of Russia

Reduction of yields and alteration of valuable and not valuable species ratio can be observed in all European seas (**Fig.** 53, 54, 25, 27, 31). Catch structure modification is the general trend. Alongside decrease in yields smaller fishes earlier regarded as not valuable have come to form their core.

The Barents Sea fisheries dynamics (**Fig.** 53, 31) show that large scale fishery in this basin started only in the 1950s that is very much later than in the Southern seas. Average catch was very high reaching 3 mln tons and it mainly consisted of valuable fishes and herring is one of them. By the early 1970s, as herring stock was exhausted, new species (capelin, Arctic cod) were introduced into mass extraction comprising more than half of total catch. In several years Arctic cod suffered the fate of herring. At the same time there were registered peak catches of halibut, perch, wolf fish (200,000 t).Traditional fish deficiency was helped by extensive extraction of capelin. Capelin vanished in 1986, yet herring stock had not recovered. That period is characterized by the lowest yields (**Fig.** 55).

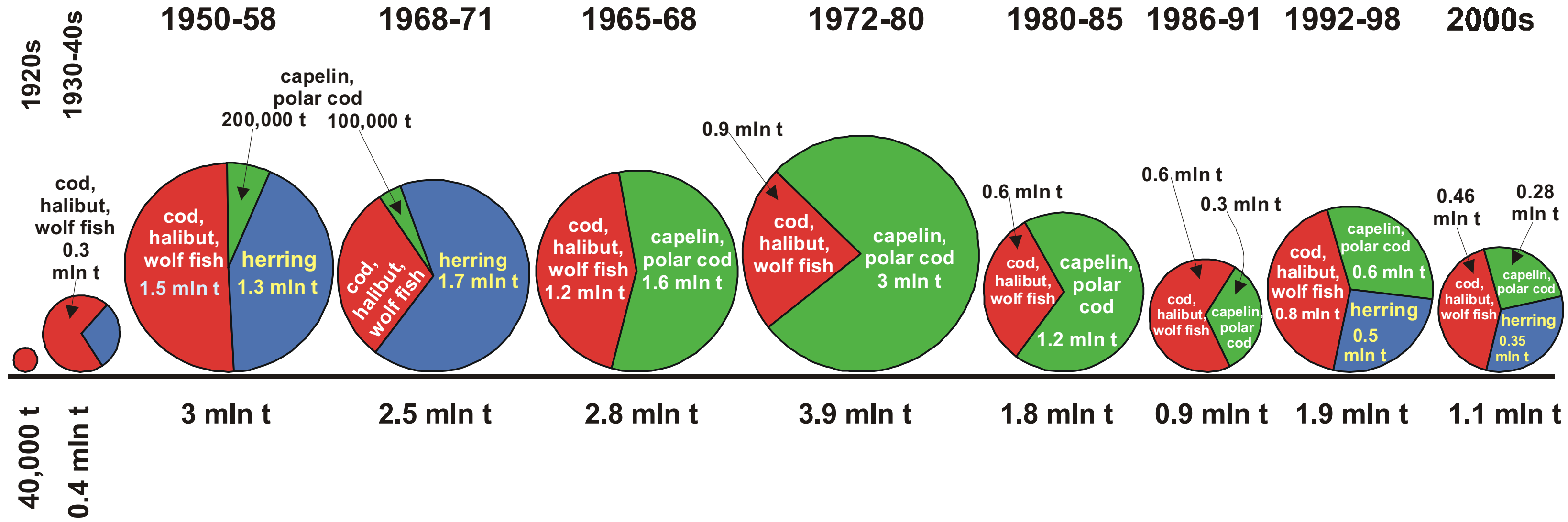

Fig. 53. Generalized scheme of dynamics of catch of both valuable and low-value fish species in the Barents Sea

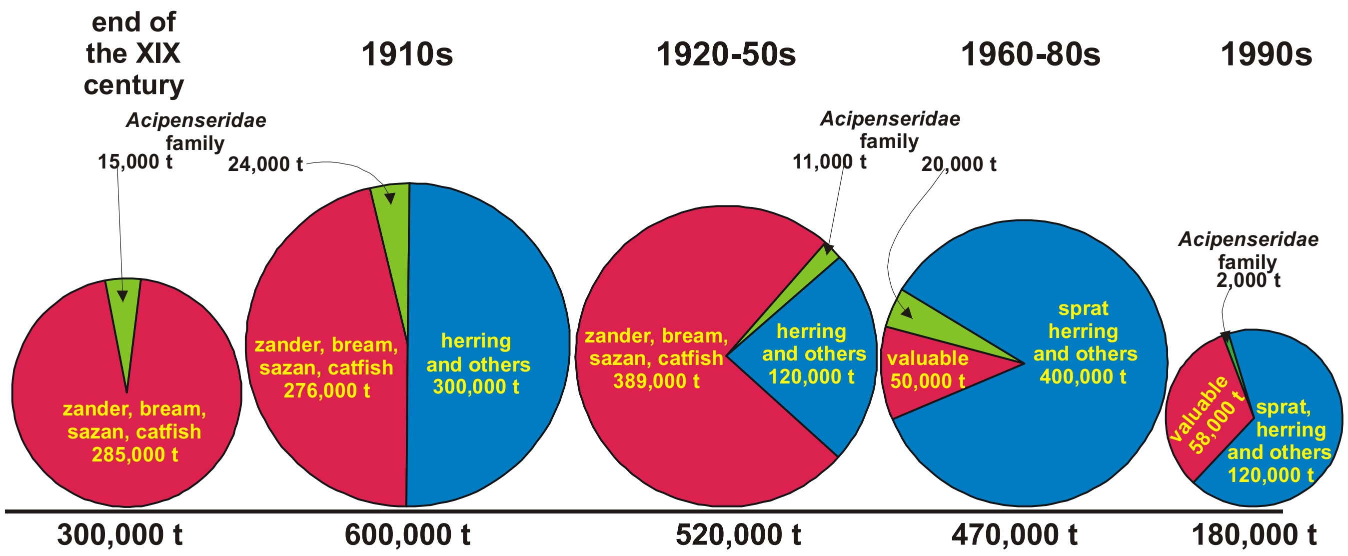

Fig. 54. Generalized scheme of dynamics of catch of both valuable and low-value fish species in the Caspian Sea (by the materials of Ivanov V. P. 1999)

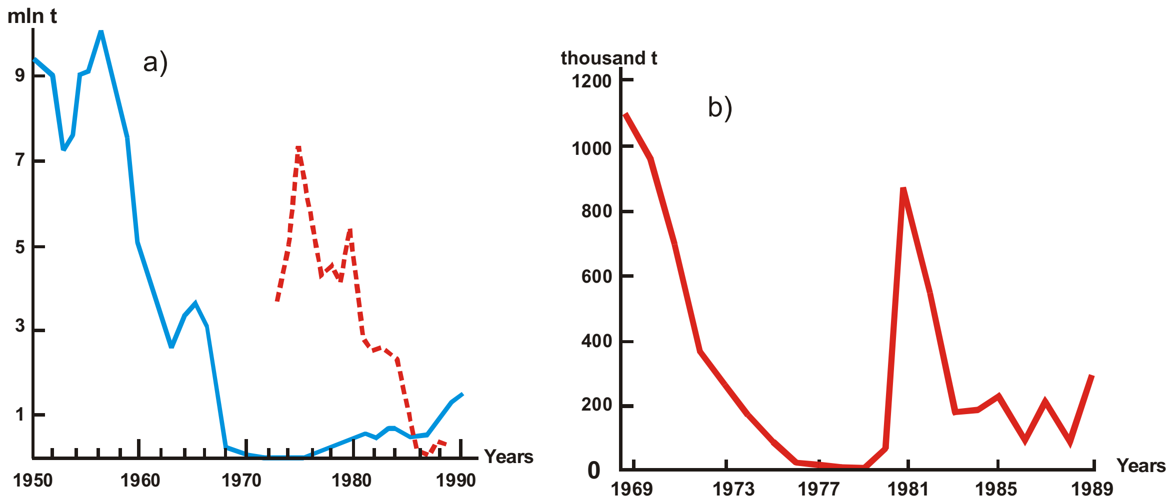

Fig. 55. Dynamics of abundance of capelin and the spawning Atlantic- Scandinavian herring (a) and polar cod (b) due to over-exploitation (Vader et al. 1989, I. Borkin's personal message)

That was the fish resources exploitation trend in the richest of the seas studied in this book. Barents Sea cod deserves separate analysis as key element of the ecosystem (**Fig.** 56). It has been heavily exploited on account of its high commercial value despite shortage of food, regardless of biological consequences. Nearly half of its stock is extracted annually instead of admissible quantity equal to one fifth which is a sure way to degradation of Barents sea cod (**Fig.** 53, 54).

Cod stock depletion is accounted for not only by overexploitation of cod itself but also by extraction of its food objects, capelin and shrimp. Overcatch of the latter reduces food resources, leads to grazing upon juveniles of its own kind (cannibalism), growth rate decrease and population reproductive capacity reduction which hinder recovery of the stock despite occurrence of rich year-classes. Overcatch of Arctic cod and capelin caused decrease not only in stock of cod but also in number of seals that had to alter their habitual routes of migration because lack of food and perished near Norwegian coast. In the bird colonies population of birds feeding on fish decreased sharply (**Fig.** 64). Cod subsistence on other food objects brought misbalance into the Barents Sea ecosystem (Orlova and Matishov 1993).

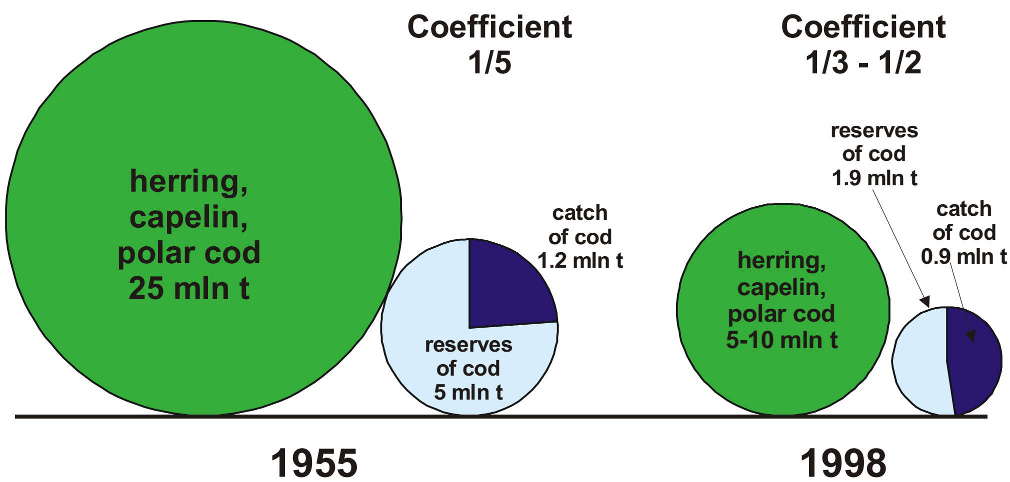

Fig. 56. The Barents Sea cod catch compared to its own stock and to stocks of other pelagic fishes

The detected trends manifest themselves much more distinctly in the Southern seas. Sturgeon stock exploitation in the Caspian Sea started as early as the 16th century. By the end of the 19th century, the catch of valuable species amounted to 300,000 t including 40,000 t of sturgeon. Ultimate overcatch took place by the mid of the 19th century. It is noteworthy, that it had happened before the dams were erected and agriculture was flooded with chemicals. Over last 40 years sprat is predominant in catch pattern and negligible catch of sturgeon is maintained by rearing (**Fig.** 54).

The Azov Sea represents accelerated modification of the Caspian model of bioresources exploitation. In the course of 150 years one of the world's richest reservoir has completely lost its commercial importance. Only valuable fishes were captured until the middle of the 20th century despite continuous decline in yields. Quantitative breakthrough happened in the 1950–60s when mass fishing of white sturgeon and Caspian sturgeon food object (Azov goby) added to other negative factors which will be discussed later. Fate of the Azov Sea is as tragic as that of the Aral (**Fig.** 25). The role of seabirds in the ecosystems should not be underestimated. Multimillion bird colonies graze upon small fish, crustaceans and supply coastal waters with biogens. Exhaustion of not valuable fish caused food deficiency and dramatic decrease in populations of bird colonies. Coincidence in time of heavy fishing and poor reproduction leads to collapse of fish stock itself which is followed by degradation of bird colonies.

Dramatic multifold fall in murre population during one year happened on the Bear Island. Food deficiency resulted in dozens of millions deaths of birds. Migrants from north Atlantic started a gradual occupation of vacant niche.

The situation of bioresources overexploitation is obviously present in all seas. Its consequences affect not only commerce but ecosystem, too. Exhaustion of not valuable mass fishes alone undermined food basis of valuable fish, birds and sea mammals.

Illegal fisheries, small fish discarding, bycatch issue (unused opportunities of multispecies fishery) cause serious concern. All these factors connected with inadequate or non-existent legal regulation, have recently acquired particular importance, as Russian ocean fishery declined.

INTRODUCTION OF NEW SPECIES

Introduction is somehow justified in sea basins with degraded marketable species sector. But proper consideration from the biological point of view has not always been given to it.

Thus food basis of king crab turned out to be more scarce than in the Far East, though feeding rate remained at the same level (**Fig.** 57). King crab diet in the Far East seas primarily consisted of mollusks, but in the Barents sea they mostly graze upon Echinodermata (40% of weight), Polychaeta, fish (Gerasimov and Kotchanov 1997). On account of ample fish and larvae consumption by king crab they are supposed to be responsible for elimination of henfish stock which is a valuable marketable species of the Barents Sea coastal area (Personal message of Karamushko). Annual catch of henfish only by Russian trawlers amounts to 1,500–2,000 t.

A series of studies on Southern seas is devoted to analysis of the consequences of planned introduction of ichthyofauna representatives. For example, studies on fishes occupying differ-

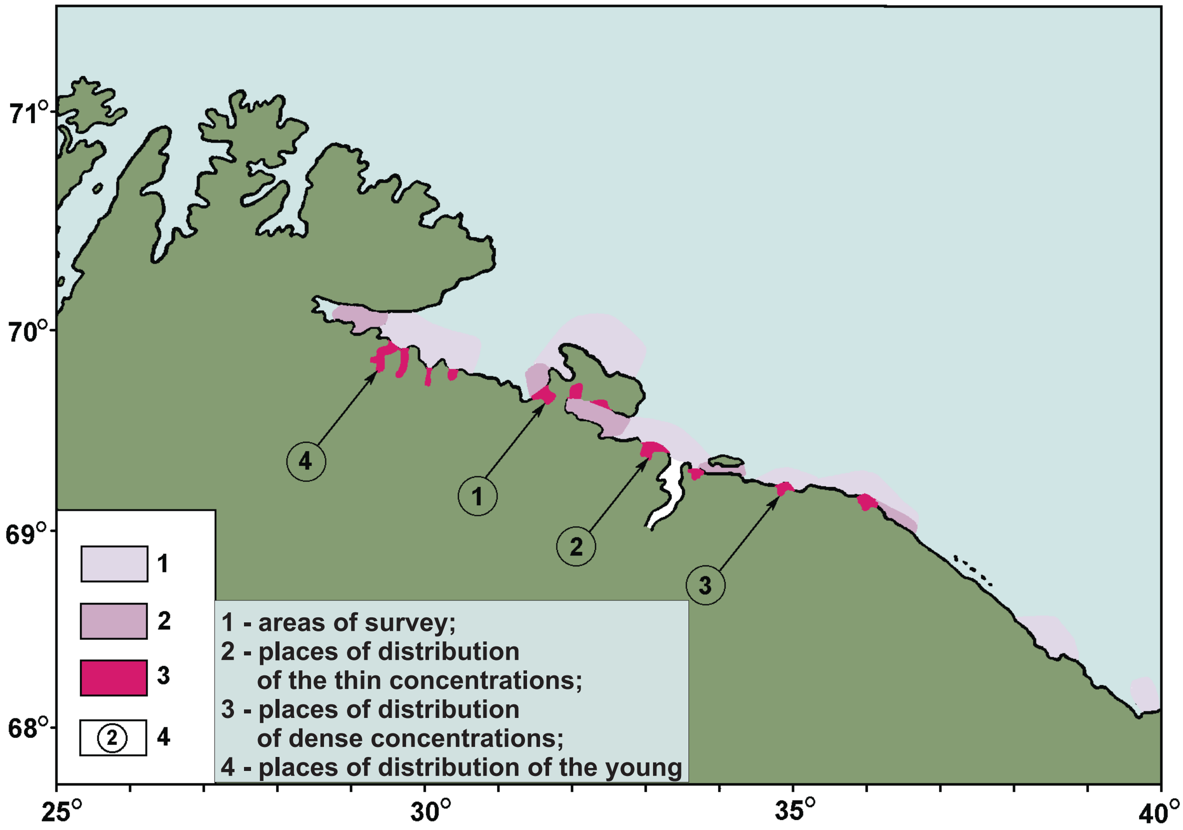

Fig. 57. Distribution of the Kamchatka crab concentrations in the Barents Sea in July-August 1993

ent levels in the food web: white and black amur (plant feeders), pelyad (zooplankton feeder), ship (benthos feeder), zander (predator), leaping grey mullet and golden mullet (detritus feeder) (Rykova 1997). Silver carp was introduced to Tsymlyansk reservoir with respect of phytoplankton primary production like white amur was introduced to deltas of the Don and Volga rivers on the assumption that it would graze upon water surface plants. However, expected ameliorating and commercial results were not achieved, at least «blooming» and eutrophication of delta never stopped. In all cases attempts to produce marketable stocks of above mentioned fish failed.

Leaping grey mullet and golden mullet (detritus feeders) were trying to fit into free food web niche in the Caspian Sea. Abundance of these species obviously matches food basis. Commercial effect is clear, because they grew into commercial stock without interfering with the other species. Introduction of species into reservoirs regardless of their trophic level leads to serious changes in the original ecosystem.

Trophic interrelations that entered the scene after introduction of haarder into the Azov Sea remain unrevealed, too. In new environment haarder size-weight growth, maturation rate growth and broadening of its food preferences have been registered (it started feeding on some kinds of benthos besides detritus) (Gubanov and Serobaba 1997, Pryakhin 1998).

This is a case of undesirable competition of haarder with aboriginal species, especially with unique sturgeon family which are known to be benthophages and predators.